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Aircraft Pollution: Noise and Other Types



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AIRCRAFT POLLUTION: NOISE AND OTHER TYPES

by

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ABSTRACT

The following types of pollution relating to aircraft operations are discussed: noise pollution, air pollution, water pollution, and solid waste pollution.

The cost to society in terms of the effects of these pollutants on health and on the environment is covered and methods of dealing with these pollutants are outlined. The discussion is related to the Canadian experience, including the problem and the solution.

The federal Environmental Assessment and Review Process which ensures that environmental effects are taken into account early in the planning of federal projects is described.

RÉSUMÉ

Le present document étudie divers types de pollution liés aux mouvements des avions, nommément la pollution par le bruit, la pollution de l'air et de l'eau et la pollution par les résidus solides.

Le document traite du coût social des incidences de ces pollutions sur la santé publique et sur l'environnement et expose les méthodes destinées à combattre ces répercussions. L'étude porte sur l'expérience canadienne, problème et solution.

On décrit le Processus fédéral d'évaluation et d'examen en matière d'environnement, qui assure la prise en compte des incidences environnementales dès les premières phases de la planification des projets fédéraux.

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1 INTRODUCTION

Increasing mechanization and population densities in our modern society, coupled with higher standards of living and education, have in recent years resulted in a growing concern about pollution and its effects on the environment. The era of sporadic individual complaints to government is being rapidly superseded by one where strategic concerted action by irate citizens' interest groups is becoming commonplace. As a result, governments are becoming increasingly involved with the problem of environmental pollution. In Canada, for example, the Environmental Protection Service of the Department of Fisheries and the Environment for fiscal year 1975-76 had a staff of approximately 800 with a total budget of \$25 million.

A major source of environmental pollution is the transportation industry. In Canada, private automobiles alone account for 40% of all air pollution emissions. The aviation industry is responsible for various types of pollutants including air pollution, water pollution, solid waste pollution, and, in particular, noise pollution.

Although it is difficult to say which of these pollutants has the most significant adverse effect on people, there is no doubt that noise is responsible for the majority of complaints concerning aircraft operations; various surveys have indicated that for residents living in the vicinity of airports, noise is the greatest environmental concern. Although air, water, and solid waste pollution resulting from aircraft operations may contribute significantly to the pollution problem in the vicinity of an airport, aircraft noise is by far the major noise problem for local residents.

An indication of the magnitude of the aircraft noise problem is given by the fact that in the United States in 1962 plaintiffs were seeking \$14.5 million in airport noise litigation. This figure had reached \$200 million by 1968, and in 1971 it had climbed to approximately \$2.5 billion. Present indications are that the total sought by plaintiffs from airport operators as a result of excessive aircraft noise exceeds \$5.5 billion (1). Approximately \$23 million has already been awarded to schools and private individuals (2). It is estimated that approximately fifteen percent of Canadians live where aircraft noise is excessive.

One possible explanation for the public's greater and more vehement attack on airport operators to stop excessive noise pollution, compared to other types of pollution, is the fact that a more obvious cause-effect relationship exists between noise pollution and its source. In other words, although residents in the vicinity of an airport may be aware of local air or water pollution which may emanate from many sources, the airport may not be readily identified as a major source. In the case of an aircraft flyover, however, the source of the noise is easily identifiable. Furthermore, the adverse effects of air and water pollution may not manifest themselves for some time whereas activity interference caused by excessive noise is an immediate problem to those affected.

For these reasons, it is felt that noise is the most significant pollution problem associated with aircraft operations and is dealt with accordingly in the body of this paper.

2 NOISE POLLUTION

Noise from aircraft has adverse effects on people and can have adverse effects on wildlife and other animals. In addition, pressure changes associated with the aircraft sonic boom can in some cases produce damage to structures. This section commences with a brief discussion of the numerical representation of aircraft noise, followed by some comments on its adverse effects and current impact, and concludes with a discussion of the various means of controlling aircraft noise.

2.1 Numerical Representation of Aircraft Noise

The loudness of a sound as perceived by people at some instant in time can be represented by a quantity called the A-weighted sound pressure level, which is often referred to simply as the A level. The A level is expressed numerically in A-weighted decibels, and is written dBA or dB(A). The A-weighting refers to the fact that the sound is frequency weighted to discriminate against very high and low frequencies to which the ear is less sensitive. Sound is measured logarithmically (in decibels) to approximate the response of the human ear.

For some purposes it is useful to represent noise by a quantity referred to as the A-weighted equivalent level (L_{eq}) or simply the equivalent level. The equivalent level is expressed in dBA and represents the A level averaged over some period, such as an hour, 8 hours or an entire 24 hour day. A quantity called the day-night equivalent level (L_{dn}) adds a ten decibel penalty to noise occurring between 10:00 p.m. and 7:00 a.m. and is intended to represent the fact that nighttime noises are usually more annoying and are more likely to lead to other adverse effects than are daytime noises. It follows that the day-night level is always 1 to 10 dBA greater than the 24 hour equivalent level for the same 24 hour period.

In the U.S.A. and in Canada, the noise environment near an airport resulting from aircraft operations is often expressed in terms of a quantity called the noise exposure forecast (NEF). The noise exposure forecast is similar to the day-night level, but it contains pure tone corrections. The procedure for sound averaging in NEF is different to that of L_{dn} ; the noise exposure forecast represents nighttime flights as being somewhat more annoying

relative to daytime flights than does the day-night level and is not expressed in decibels. The following approximate relationship exists between the noise exposure forecast and the day-night level:

$$L_{dn} \approx NEF + 35$$

For most circumstances involving aircraft flyover noise this approximation is valid to within about one decibel (3).

The aircraft noise environment is represented in Great Britain by a quantity called the noise and number index (NNI). The noise and number index differs from the noise exposure forecast in that, among other things, it is calculated separately from the daytime and nighttime periods. If there is only one type of aircraft that is noticeable at a particular point and the movements occur only during the daytime and pure tone and duration effects associated with the flyover are negligible, then the noise exposure forecast and noise number index at the location of interest are related by:

$$NEF = NNI - \log n - 8$$

where n is the number of aircraft movements occurring during the daytime period being considered (4).

2.2 The Adverse Effects of Aircraft Noise

2.2.1 Activity Interference and Annoyance. A person's psychological state is a complex of many processes including sensations, perceptions, actions, thoughts, feelings, attitudes, needs, and motives. All of these processes find expression in a person's behaviour and subjective experience. Noise, in interacting with these processes, may have adverse effects resulting in losses in work performance, speech interference, sleep disruption, annoyance, and stress.

Studies have been performed to determine the effects of noise on behaviour and, in particular, on task performance. The U.S. Environmental Protection Agency (EPA) states that, viewed as a whole, the literature on noise and performance shows that sometimes noise interferes with performance, sometimes it improves it, and usually it causes no significant changes (3).

Ando, Nakane, and Egawa studied the performance of children doing mental tasks (5). There were short periods during which the children produced substantially less than their own average rate of work, and it was found that

especially pronounced decreases in work rate occurred more frequently in children from elementary schools in a region with relatively large amounts of aircraft noise than in children from elementary schools in a region with less aircraft noise. It should be noted that this relatively frequent occurrence of decreased work rate of children from schools in noisy areas was found to occur when the children were doing tasks while exposed to relatively little aircraft noise. It appeared, therefore, to be related to prior exposure to noise rather than to exposure during the task.

Research has indicated that aircraft noise can affect sleep and that changes in sleep state without awakening may occur (6,7). Although the significance to health of sleep changes due to aircraft noise is not known (the relative importance of the various stages of sleep is a matter of current disagreement), social surveys and complaints indicate that sleep interference due to aircraft noise is an issue of major concern to many people.

Noise interference with speech communication is usually a masking process. The background noise increases the threshold of hearing and, as a result, few or none of the sounds necessary for satisfactory intelligibility are heard (8). Noise impairing the perception of other sounds is an important and clear cut effect, quite separate from annoyance and disturbance, although it may be associated with them. Speech, directly or by telephone or loud speaker, or any other meaningful sound such as a warning signal, may be interfered with by noise. The potential dangers, as well as the inconvenience and disruption of work or leisure due to these effects, are self-evident. Various noise studies in Canada have shown that transportation noise is responsible for speech communication interference for a significant number of Canadians (9,10,11). This result is to be expected since transportation noise is often responsible for noise levels of 70 dBA or higher, at which time it becomes difficult to communicate at distances greater than 4 feet (3).

The Organization for Economic Co-operation and Development has reported that studies on noise annoyance have been done in various countries and the average annoyance produced by various aircraft noise environments in the different studies has been found to be similar (12). However, although the average annoyance for various noise environments in different places has been

found to be about the same, it has also been found that there are very substantial deviations in individual reactions.

EPA has stated that an outdoor day-night level in residential areas of 55 dBA is compatible with the protection of public health and welfare (13). This level was arrived at after consideration of various adverse effects of noise including speech interference, sleep interference, annoyance, and hearing damage. It is stated that lower levels may be required in some circumstances. EPA indicates that this level is provided as a basis for setting standards, but that it is necessary also to consider other factors such as: the relationship between costs and benefits; the nature of noise problems in any particular area; local aspirations; and the means available to control environmental noise.

Abey-Wickrama et al published a study on admissions to a psychiatric hospital of persons living in the vicinity of London's Heathrow Airport (14). The results of this investigation indicated that the rate of admissions of people from particularly noisy parts of the region was higher than the rate for less noisy areas. However, in a later survey the difference in admission rates for the particularly noisy and less noisy areas was found not to be statistically significant (15).

2.2.2 Hearing Loss. Although hearing loss may be caused by a variety of drugs and chemical agents, by certain disease organisms, by traumatic injury, and by aging, there is little doubt that a major cause of hearing loss today is overexposure to excessive noise. It has been estimated that 10 to 20 million persons in the United States have some degree of hearing impairment (16). This means that in Canada approximately 1 million people might be expected to have impaired hearing. Most of the hearing impairment is presumed to be due to occupational noise exposure (17,18), although exposure to non-occupational noise may also result in permanent hearing damage (3,19,20).

EPA has recommended a maximum daily Leq (24) of 70 dBA to protect virtually the entire population against eventual hearing loss due to excessive noise exposure (13).

It has been estimated that 1.5 million Americans live where the

day-night noise level due to aircraft exceeds 75 dBA (21). If we assume that the difference between daytime and nighttime levels for Ldn 75 is of the order of 4 dBA (13), it follows that this day-night level corresponds roughly to an Leq (24) of 71 dBA, with the result that approximately 1.5 million Americans live in areas where the Leq (24) from aircraft exceeds the individual noise exposure of 70 dBA recommended by the EPA.

It should be noted that environmental aircraft noise is intermittent and, as stated by the EPA, for some types of intermittent noise higher values of Leq (24) might be justified. Also, it should be noted that the above population figure refers to exposures of the areas where people live and not the exposure of the people themselves (22). Since people will often be indoors or away from their home during each day, their personal noise exposures will tend to be different from the outdoor noise levels at their residence.

It has been found that aircraft operations over residential areas in the vicinity of Los Angeles International Airport consistently produce maximum noise levels in the range from 103 to 115 dBA (22,23,24). Ward, Cushing, and Burns exposed people in a reverberant room to recorded takeoff and landing noises with 110 dBA peak levels which occurred at 90 second intervals for a period of six hours (26). They remarked that some of the landing noises might constitute the beginnings of a hazard if the peak levels were increased, but concluded that the possibility of suffering a measurable permanent hearing loss as a result of aircraft flybys in a residential neighborhood is remote. They stress the need for substantial allowance for intermittency in setting hearing-damage noise standards.

As mentioned above, large numbers of people are exposed to both occupational and non-occupational noise environments which can damage the hearing. Aircraft noise exposure which by itself may be innocuous may contribute to hearing damage when it occurs in combination with occupational and/or non-occupational exposures; however, there is no data available on the extent to which this occurs.

Finke et al state that studies in Germany have indicated that individual hearing loss grows with aircraft noise but, aside from a comment on

the statistical significance of the results, no details are provided on the data and analysis or on the numbers of persons afflicted (27).

Generally, aircraft noise levels which are capable of causing hearing impairment are significantly higher than those capable of causing activity interference and related effects and measures which are intended to alleviate these latter effects will tend to diminish noise exposures in such a way as to reduce the possibility of hearing damage.

2.2.3 Other Physiological Effects of Noise. The ear is the primary receptor for sound and, with a few exceptions, the way in which sound is introduced into a person's nervous system. A person's response to sound can be extremely complex, and can involve directly and indirectly many physiological mechanisms. It has become increasingly clear that some of these secondary physiological effects of noise on people are measurable, and are of possible importance to their behaviour and health. Because of rather subtle and small responses to noise by nonauditory systems compared with the responses of the auditory system, it has been difficult to demonstrate or elucidate these effects, or to distinguish them from effects possibly caused by factors other than noise (28).

Noise affects both the circulatory system and the nervous system. Intense sounds can induce stress and repeated exposure to aircraft passby noise might possibly produce stress which has deleterious effects on the health; however, the degree of significance of these effects to health has not yet been established.

Ando and Hattori studied populations of children in the vicinity of Osaka International Airport (29). It was found that children whose mothers moved to the noisy airport regions before or during the fifth month of pregnancy were less disturbed by noise than children whose mothers moved to the noisy airport region after this time. It was also found that the birth rate of low birth-weight children was higher in noisy airport regions than in quieter regions. No factors to explain for the differences in birth-weight other than noise levels could be found.

2.2.4 Effects of Sonic Booms. Aside from producing psychological stress, a sudden noise such as a sonic boom can produce orienting and startle

reflexes. In a precarious situation such as while operating certain machinery or handling sharp objects or corrosive liquids, uncontrolled muscular actions associated with these reflexes could indirectly produce harm; however, except in such special indirect circumstances there is no concrete evidence that orienting and startle reflexes associated with aircraft noise have a significant effect on human health.

The introduction of commercial SST aircraft of the present type in overland supersonic flight would make it virtually impossible for people to avoid boom exposed areas in the way people may, if desired, avoid noise polluted areas in major cities at the present time (30). This would expose a large percentage of the population to aircraft noise, almost without the possibility of escape.

It appears that the inanimate structures most susceptible to significant damage are buildings and that the damage will mainly be confined to brittle secondary structures such as glass and plaster (31). Magnification of sonic boom pressures can result from factors such as atmospheric effects, acceleration of the aircraft to supersonic speeds, and turning manoeuvres. There is an extremely small but non-zero probability of a highly magnified boom from a commercial SST causing the collapse of a building whose primary structure is very weak or faulty. Warren has stated that he considered the possibility of damage by commercial SST sonic booms to historic buildings (32). He concludes that the sonic boom is a significant contribution to the noise and vibration exposure of a cathedral, but the levels of vibration induced by booms would be well below the level that would cause instantaneous damage.

There is also a possibility that avalanches might be triggered by sonic booms (31), but there is no direct evidence of a cause and effect relationship.

2.2.5 Effects of Noise on Wildlife and Other Animals. Noise produces the same general types of effects on wildlife and other animals as it does on humans, namely: hearing loss, masking of communications, and behavioral and non-auditory effects. A mass hatching failure of Dry Tortugas Sooty Terns appears to have been caused by sonic booms occurring in 1969 (33); however,

extremely intense booms resulting from aircraft flying at very low altitudes were involved, and booms caused by high-flying aircraft passing over the Dry Tortugas during several subsequent years do not appear to have been particularly disturbing to the colony.

It is noted that panic behavior such as piling up or huddling could lead to survival problems for wildlife (34). Also, avoidance behavior could restrict access to food or shelter and therefore adversely affect an animal's or even a species' chances for survival.

Very little research has been done to date with respect to the adverse effects of noise on animals; however, the EPA suggests that until more information exists a simple approach is to assume that animals will be at least partially protected by application of maximum levels identified for human exposure (13).

2.2.6 Social Costs of Aircraft Noise. Aircraft noise imposes many costs on both the individual and society. As mentioned above, in the United States approximately \$5.5 billion is currently being sought from airport operators by plaintiffs as a result of excessive aircraft noise. Public reaction to noise has been a major factor in the slowdown of airport expansion and, in some cases, the cancellation of new airports. This has placed additional financial burdens on airport operators and in turn on the public. The Federal Aviation Authority of the U.S. recommends that one of the costs imposed by aircraft noise on the individual be represented by the decrease in property values in the vicinity of airport (35). It should be noted, however, that this approach has been criticized because in some cases airports may attract industry and other development which may cause an increase in property values in the vicinity of the airport.

The above costs are tangible and are relatively easy to assess. However, the costs to the individual resulting from activity interference and annoyance are largely intangible and must be determined indirectly. Richards suggests that the minimum value of the disamenity of seriously annoyed persons living in a given airport area must be the total cost of moving to a quieter area plus the additional cost of a house in a quiet area (36). One judge in the U.S. has valued the annoyance, inconvenience, discomfort, mental

distress, and emotional distress suffered by airports' neighbours as \$400 per person per year for all residents within the NEF 30 contour (35). Using this figure for Canada, the total cost of aircraft noise on local residents would be approximately \$200 million a year.

2.3 Current Aircraft Noise Impact

It is estimated that 35 million Americans live in areas where the Ldn due to aircraft noise exceeds 55 dBA, the level identified by the United States Environmental Protection Agency as a maximum in residential areas in order to protect against significant activity interference (37). Of these, over eight million can be expected to be highly annoyed and one million to complain (13). As stated before, it has been estimated that 1.5 million Americans live where the average noise level due to aircraft exceeds 70 dBA, the level recommended by the EPA as a maximum in order to prevent significant hearing loss (37). Of these, approximately 55% can be expected to be highly annoyed and 17% to complain (13). Again it must be noted that this level does not represent the actual daily noise exposure of those living in the vicinity of airports; it represents the average daily noise level outdoors at the residence.

Jones provides the results of social surveys in three U.S. cities in which respondents indicated the percentage of noise from each of several sources contributing to the noisiness of their environment (38). The average judgement of the respondents was that motor vehicles contributed the greatest percentage (55%) of the noise in their environment and the next greatest percentage (15%) was due to aircraft. It should be noted that these averages were calculated by including the responses of people who did not consider that aircraft contributed any noise to their environment. In the group consisting only of people who considered that aircraft did contribute to the noise of their environment, the average judgement was that aircraft were responsible for 44% of the environmental noise.

2.4 Aircraft Noise control Measures

There are a number of ways in which the adverse effects of aircraft

noise can be reduced. Each measure has advantages and disadvantages associated with it in terms of economic and technological feasibility, time for implementation, and time for results to become apparent. The effectiveness of these various measures should be judged on the basis of a cost-benefit analysis - the benefit measured, perhaps, by a reduction in the social costs of the noise as discussed previously.

2.4.1 Aircraft Noise Certification. Perhaps the most obvious method of reducing aircraft noise is to control the actual level of noise produced by the aircraft. An example of noise certification requirements is the Federal Aviation Regulations of the U.S. Until a recent amendment required increased compliance with the certification requirements, these regulations applied to only one fourth of the current U.S. fleet (39). Retrofitting existing aircraft is an interim solution; however, designing new aircraft to meet certification standards is more cost-effective. It should be noted that total compliance with certification standards will not in itself eliminate the aircraft noise problem since, in addition to desired levels, these standards take into consideration technological feasibility and cost of compliance.

2.4.2 Aircraft Operational Procedures. The noise emitted by aircraft in the vicinity of airports may, within limits, be modified by changes in the rate of change of altitude during takeoff and landing. Such techniques for controlling aircraft noise emissions are often referred to as aircraft operational procedures. A recent regulation of the F.A.A. requires that civil jet airplanes use minimum landing flap settings during landing operations (40). The reduced flap settings minimize drag on the aircraft and hence reduce engine noise emissions since less engine power is used. The F.A.A. has proposed that there be a delay in deployment of landing flaps in order to reduce noise emissions, but there has been some criticism of this measure for safety reasons (41).

2.4.3 Airport Operations. Aircraft noise near an airport may also be controlled by: limiting the number of aircraft that operate at an airport each day; imposing nighttime curfews; concentrating aircraft operations on "preferential runways" for which takeoffs or landings are known to result in minimum adverse effects on the surrounding community; and, as an extreme measure, relocating the airport. Each situation must be analyzed in detail, however, as changes made may not reduce noise levels as much as is felt intuitively. It has been shown that in order to have a significant reduction in Ldn (i.e. greater than 3 decibels), more than half of the existing flights at an airport must be eliminated. If these flights are relocated at a new facility where similar numbers of residents are exposed to the noise, an increase in the total number of residents who are highly annoyed will result. Taking the case of the nighttime curfews where nighttime flights are transferred to the daytime, if an airport has an even distribution of flights throughout the twenty-four hour day, then a reduction in Ldn of more than 3 decibels will result only if at least two-thirds of the nighttime flights are transferred to the daytime (42).

2.4.4 Airline Noise Charge. It has been proposed to control aircraft noise through the mechanism of monetary incentives. Alexandre and Barde suggest that an aircraft noise charge be paid by airlines according to the noise levels produced by aircraft at the various airports where they operate (43). They propose a fairly simple method of calculating the charge based on the amount by which the aircraft noise exceeds a specified threshold, and they also propose a more complicated charging procedure based on a calculation of land areas impacted to various extents by noise and of the numbers of annoyed people living within the land areas thus determined.

2.4.5 Land Use Controls. The adverse effects of aircraft noise may be limited by means of controls on land usage in the vicinity of airports. Such controls can be achieved, for instance, through controls on land development implemented by local governments and through restrictions on financing of development projects by national governments. The controls may deny support or permission for construction altogether or may provide permission subject to the condition that adequate sound insulation be provided as is done, for

example, by the Central Mortgage and Housing Corporation in Canada. Land use controls can also be used where there are existing residences; however, rezoning an existing residential area as a non-residential area can be a very expensive undertaking.

Appropriate use of land adjacent to an airport is a controversial issue. The airport operators can argue that residences should not be built where aircraft noise is excessive; however, municipalities and developers can argue that the airlines should not impose a usage on land which they do not own. The problem will likely only be solved through cooperation on both sides.

2.4.6 Public Education. Criticism is often leveled against those who live near airports and who complain about the noise; it is argued that these residents "should never have moved there" or that they "should get used to the noise". Unfortunately, in some cases people may not realize how severe a noise problem will be when they move into an area. Wrigley investigated the noise expectations of migrants to an area around Luton Airport and found that persons in the area who had lived farther from the airport were more likely to find the airport noise worse than expected than those who lived closer to the airport (44). Wrigley suggests that many migrants into an area subject to the known disamenity of aircraft noise fail to anticipate the true aircraft noise levels, and he suggests that in particular they have a distorted perception of the way aircraft noise nuisance is likely to decline with distance from the airport.

Information on noise which is provided to the general public may help people to choose a personal noise environment which is compatible with their individual needs and priorities. The provision of public information may serve, therefore, as a means of reducing adverse noise effects. Shultz and McMahon (45) have provided information on how to determine the aircraft noise environment in a particular location. This information is in a form which may be understood and used by a person who does not have a specialist knowledge of acoustics and does not have specialized acoustics measurement instrumentation.

It should be noted, however, that in many cases people may not have a choice. If housing is built near an airport or anywhere else that

environmental noise is excessive, a lack of suitable housing elsewhere may force people to buy these homes.

2.5 For the Future

Aircraft noise pollution is a significant environmental problem in many countries and unless appropriate action is taken, it can only be expected to increase. It is government's responsibility to react to the desires of the public and so unless aircraft manufacturers, airlines, and airport operators cooperate with local governments in working towards the reduction of the problem, national governments may be forced to take a more active role in the control of aircraft noise.

3 AIR POLLUTION

Air emissions which are considered as major pollutants in Canada are hydrocarbons (HC), carbon monoxide (CO), nitrogen oxides (NO_x), sulphur oxides (SO_x), and various forms of particulate emissions. In most cases the pollutant designation arises from the debilitary effect of the substance on the human respiratory system. For example, NO_x and some HC's are directly responsible for respiratory problems and they are also proven precursors of other pollutants, collectively referred to as oxidants. On the other hand, CO is poisonous because it reduces the capacity of the blood to carry oxygen, while many of the particulates, including some HC's, are being implicated as carcinogens. Finally, synergistic effects among various air pollutants must be kept in mind when estimating the effect of raising local concentrations of any one pollutant.

A recent concern is the possible detrimental effect of supersonic aircraft emissions on the crucial ozone layer in the stratosphere. While currently planned supersonic transport aircraft, due to their flight altitudes of 17 km and their limited numbers, are not predicted to have an effect that would be significant or that could be distinguished from natural variations, a large fleet of supersonic aircraft flying at greater altitudes could have a noticeable effect on the ozone layer.

In Canada at the present time, emissions from aircraft are an insignificant part of the total emissions, although an individual airport may contribute significantly to pollution in its immediate area. For example, site emissions from the Toronto International Airport are about 1% of the total metropolitan area emissions and, if indirect emissions are considered (for example from airport traffic), this increases to about 2%. Future projections show both an absolute gain in, and increasing percentage proportionally of, total passenger and freight miles travelled by air.

Methods of dealing with air pollution resulting from aircraft operations include locating airports according to local meteorology to minimize the potential for inversion conditions and to minimize indirect emissions resulting from city-airport commuting. Energy costs and pending U.S. regulations will help provide the impetus for more energy efficient

aircraft with reduced emissions, and these factors will weigh heavily in the reduction of emissions in Canadian air space; however, further impetus will likely be required and could be achieved with airport operational regulations and/or Canadian aircraft emission regulations. Excepting the special cases of stratospheric flights, the emissions along flight paths need not be an important parameter in route selection.

The Canadian Government is working towards a uniform, nationwide approach to the control of air pollution in Canada through its Air Pollution Control Program which has as its broad objective to define the Canadian air pollution problem, to promote the attainment of desirable air quality levels, and to control the emissions of air contaminants deemed to be a significant danger to public health or the environment.

4 WATER POLLUTION

There are two major sources of water pollution associated with air transport. The more significant problem is the release of wastes, cargo, and fuel from airports and industries located adjacent. Water pollution can also result from the release or spillage of wastes or cargo en route. There are two problems unique to airports:

- (i) the use of plane and runway de-icing fluids which produce large volumes of urea and ethylene glycol water solutions. These solutions have extremely high BOD (biological oxygen demand) ratings; and,
- (ii) the sewage from airplanes which may be capable of transmitting exotic diseases (introduced by international travellers).

The environmental effects associated with water pollution include:

- (i) physical and/or chemical contamination of water bodies;
- (ii) human health hazards;
- (iii) destruction or damage to aquatic life;
- (iv) alteration of fisheries productivity to impede or reduce sales; and,
- (v) decreased water-use potential resulting from lowered water quality.

Methods of controlling water pollution caused by aircraft operations include good design and disposal practices, and effective regulations.

In Canada, the federal Water Pollution Control Program has as its objective the clean-up of existing pollution and the prevention of pollution from new sources. This is done principally through the development and implementation of baseline effluent control regulations and guidelines for specific industrial sectors which apply uniformly across Canada, and more stringent effluent control requirements, to meet specific water quality objectives for ecologically sensitive areas not adequately protected by baseline standards. Primary legislative instruments employed are the Fisheries Act and the Canada Water Act.

The release of wastes from terminals and geographically associated industrial development is partially controlled by existing municipal,

provincial and federal legislation and controls (e.g. regulations). Eventually, the release of all such wastes should be subject to control.

The administration of the Ocean Dumping Control Act is the responsibility of the Department of Fisheries and the Environment. Under the terms of the Act, deliberate dumping of certain substances from ships, aircraft, and platforms at sea is subject to a permit. Permits contain terms and conditions, and are valid for a period not exceeding one year. Disposal of certain substances considered to be harmful to the marine environment is prohibited except in special circumstances. Special care is required in releasing certain other substances to the marine environment. Emergency dumping to avert danger to human life at sea, or to ship or aircraft, is provided for without a permit, but the incident must subsequently be reported.

5. SOLID WASTE

The main wastes generated by aircraft related operations are as follows:

- (i) wastes generated by the construction of airport and related facilities;
- (ii) wastes generated within facilities and aircraft during day-to-day operations (e.g. cafeteria, office, maintenance service and passenger carrier wastes);
- (iii) waste generated by the abandonment of infrastructure, sites and aircraft; and,
- (iv) "international wastes", which are generated on international aircraft and which may pose a health hazard.

Although these solid wastes do not generally pose a serious pollution threat to the environment, in some instances their disposal constitutes a significant problem. Furthermore, solid wastes can present serious aesthetic problems.

Of particular concern in Canada is the effect of solid waste pollution (and other types of pollution) on "northern" areas which are predominantly "wilderness". Construction activities can be particularly destructive in northern areas where permafrost conditions and delicate ecosystems prevail. The construction of transportation routes and terminal facilities generates solid wastes such as excavated fill deposits, abandoned equipment and vehicles, camp wastes, and rubble which if improperly managed can cause extensive damage to fish, wildlife and vegetation. In some areas, damage to the vegetation and subsoil stability is such that irreparable damage is incurred. The degradation of wastes in the North is so slow that some wastes such as plastic construction materials, cans and derelict vehicles persist indefinitely. Traditional methods of solid waste disposal are not successful in Arctic areas because of extensive permafrost. In addition, the extremely high cost of transporting waste for proper disposal (construction waste, crash debris, aviation fuel cans, etc.) and the absence of "social pressures" to do so contribute to the uniqueness of the problem.

Special problems such as wildlife attraction to garbage are very characteristic of northern areas.

Methods of reducing the detrimental effects of solid waste on the environment include:

- (i) the use of the latest handling and disposal procedures and techniques during construction stages and operation of airport facilities;
- (ii) proper finishing of airport sites to avoid subsequent erosion;
- (iii) particular attention in wilderness areas to the selection of transportation alternatives and waste management to minimize environmental damage and aesthetic pollution;
- (iv) consideration in construction of aircraft to maximize both life durability and recycling of all materials on disposal; and,
- (v) special disposal methods for international wastes.

In Canada, the handling and disposal of waste and toxic materials is covered by a range of relevant legislation and guides. These include the Arctic Waters Pollution Prevention Act, the Canada Shipping Act, and the Territorial Lands Act. There are also various ordinances of the Territorial Governments and Government Guidelines. For the management of wastes in Arctic areas, specific guidelines have been developed. In addition, there is much unpublished information and expertise available in the Department of Fisheries and the Environment on solid waste management and contingency planning. This, along with expertise from other government agencies, can be brought in at the ground stage in the planning of transportation systems to ensure the best technology is incorporated in the initial design phase.

6 ADDITIONAL CANADIAN FEDERAL POLLUTION CONTROL MEASURES

Within the Canadian Department of Fisheries and the Environment there are two other groups which deal with specific aspects of the general pollution problem. These are the Environmental Emergencies Branch and the Contaminants Control Branch.

6.1 Environmental Emergency Branch

One specific type of pollution occurrence is the sudden introduction into the environment of a pollutant in sufficient quantity to pose a direct threat to man or other forms of life. This is termed an "environmental emergency". In the transportation industry, environmental emergencies are usually caused by fuel spills or the release of dangerous materials which are being transported.

Spills of aviation fuel occur at government-controlled airports in Canada at the rate of approximately 700 per year. Spills of over 150 litres are reported to the Regional Environmental Emergency Coordinators who, as the situations dictate, may take further action. Many of the spills are small, that is under 150 litres, and the procedure with these spills has been to use absorbent materials to remove them. The current practice with spills that are large or pose a safety hazard is to apply foam to the spill and flush both components into the storm sewer system. This method is not environmentally acceptable. Each year at airports in Canada, about 10 spills of cargo occur which typically involve small containers of various materials. Another 15 spills occur per year which involve aircraft on runways or in the air. A very typical incident of this sort is the jettisoning of spray insecticide from an aircraft in the event of an in-flight emergency. The product, released upon a small area in concentrated form, may have adverse effects on the environment. Another incident of this sort involves the crash of an aircraft with a load of hazardous material. In summary, spill incidents of petroleum products or other hazardous materials involving aircraft or airports occur with relatively high frequency.

The Environmental Emergency Branch was formed in 1972 to coordinate the response of the Canadian government to spills of oil and other hazardous materials. The Branch includes a contingency planning division, a research and

development division and the National Environmental Emergency Centre. The role of the Environmental Emergency Branch is to coordinate the government response to such spills and also to assess the effects on the environment and recommend appropriate action. Current activities of the Branch include:

- (i) conducting discussions in order to find a more environmentally acceptable method of dealing with fuel spills; and,
- (ii) working towards an improvement of the state-of-the-art in the prevention and control of spills of fuel and other hazardous materials.

6.2 Contaminants Control Branch

The Contaminants Control Branch administers the Environmental Contaminants Act which ensures the provision by industry of information required by government and the undertaking of tests on hazardous chemicals in order to evaluate their potential hazards. Unlike previous legislation (Food and Drug Act, Hazardous Products Act and the Clean Air Act), the Environmental Contaminants Act provides the power to effect a systematic overview of the problem of contamination of the Canadian environment by a substance regardless of source, use, product or medium, and to apply the appropriate controls in those cases where other legislation does not apply. Under the terms of the Act, the federal government may provide for the control of chemicals which may be disseminated in the environment, are persistent, and which are harmful to human health or the environment. These controls may restrict the release, use, or incorporation of such chemicals in domestic or commercial products.

The transport of dangerous goods presents a potential source of discharge of contaminants into the land, air or water media. The discharges are characterized by the sudden release of dangerous substances, such release being accidental, deliberate, or as a result of negligence. The release of contaminants and subsequent exposure may pose a serious threat to human health and to living resources such as fish and wildlife, and to ecologically sensitive areas (Arctic) through toxic effects. Other hazards such as fire and explosion associated with the release of material may arise. Of particular concern at the present time is the current practice of transporting

radioactive wastes by air and the possibility of release over densely populated areas. The proposed Transportation of Dangerous Goods Act and Unified Transportation Code are intended to regulate the transport of dangerous materials and thereby prevent accidental release.

7 FEDERAL ENVIRONMENTAL ASSESSMENT AND REVIEW PROCESS

In December 1973, the Cabinet of the Government of Canada decided to establish an Environmental Assessment and Review Process for projects initiated by the federal departments and agencies and those for which federal funds are solicited or which involve federal property.

All federal departments and agencies are bound by the Cabinet decision except proprietary crown corporations and regulating agencies which are "invited" to participate in the process. The Minister of Fisheries and the Environment, in cooperation with the other federal ministers, is responsible for implementing the Environmental Assessment and the Review Process to ensure that:

- environmental effects are taken into account early in the planning of new federal projects, programs and activities;
- an environmental assessment is carried out for all projects which may have an adverse effect on the environment before commitments or irrevocable decisions are made and projects with potential significant effects are submitted to the Department of Fisheries and the Environment for review; and,
- the results of these assessments are used in planning, decision-making and implementation.

The basic principle underlining the Process is one of self-assessment. Federal departments and agencies are initially responsible for assessing projects which they initiate or sponsor (in terms of federal funds or property) and deciding on the significance of the anticipated adverse environmental effects. Whether potential adverse effects are considered significant or not depends on the judgement of technical and environmental specialists within the government who also take into account the potential for concern and controversy that a project might create in the public and within professional communities. Projects with significant effects are referred to the Environmental Assessment Panel established within the Department of

Fisheries and the Environment for a formal review. In special cases where a federal project commands wide public interest, the Minister of Fisheries and the Environment, in cooperation with the other ministers concerned, may establish an Environmental Review Board external to the federal public service to carry out the formal review.

The first step in the process is the screening procedure. As early in the planning phase as possible, a department screens projects and activities for which it is responsible to identify potential adverse environmental effects. Guidelines are available to help departments with this task. As a result of this action, one of the following three decisions is possible:

- (i) there are (a) no anticipated adverse environmental effects associated with the project or (b) the anticipated environmental effects are known and are not considered significant;
- (ii) the nature and scope of potential environmental effects cannot be readily determined during the preliminary screening; or,
- (iii) the anticipated adverse environmental effects are considered to be significant and the project requires a formal environmental review by the Environmental Assessment Panel.

If the first decision is made, the department concerned is responsible for implementing measures: a) required to prevent or mitigate the adverse environmental effects identified; and b) to satisfy all other legislative, regulatory and Cabinet requirements associated with the development of the project. However, no further reference to the Environmental Assessment and Review Process is necessary.

In the second case, a more searching examination called the Initial Environmental Evaluation (IEE) is carried out by the department concerned. Guidelines prepared by the Department of Fisheries and the Environment covering such project classes as Airports, Nuclear Plants and Linear Transmission Lines (e.g. pipelines) are made available to assist federal

agencies prepare this document. The IEE provides a statement on the general characteristics of the project, the existing environmental and resource use, the potential environmental effects, the mitigating measures proposed and possible residual impacts. The alternative ways of accomplishing project are then examined and the preferred alternative(s) identified.

As in the screening procedure, the responsibility for the review of the IEE and for determination of the environmental significance of the project rests with the initiating department. In both cases, departments are encouraged to seek advice during these assessments from the Department of Fisheries and the Environment, generally through the Regional Screening and Coordinating Committees established by the department across Canada.

If the initiating department decides on the basis of the screening procedure or IEE review that potentially significant impacts are involved, the following actions take place.

- (i) Initiator refers the project to the Chairman of the Environmental Assessment Panel for a formal review. The Chairman is a permanently appointed member from the Department of Fisheries and the Environment. He (or his delegate) presides over the separate panels that are formed to review each project.
- (ii) An Assessment Panel, consisting of one member appointed by the initiator and several members from within the federal Public Service selected by the Panel Chairman, is formed. The Minister of Fisheries and the Environment may also appoint Panel members from outside the federal Public Service.
- (iii) The Panel issues specific guidelines to the initiator for the preparation of an environmental impact statement (EIS).
- (iv) At the discretion of the Minister of Fisheries and the Environment, the guidelines are made available

to the public.

- (v) The initiating agency prepares or procures an environmental impact statement based on the panel guidelines, and submits it to the Panel.
- (vi) The Panel determines the acceptability of the environmental impact statement and can or will:
 - request additional information from the initiating agency, Fisheries and Environment Canada and other agencies as appropriate;
 - make public the report (EIS) unless otherwise directed by the Minister, allowing time for public response;
 - hold public meetings;
 - determine the appropriateness and adequacy of proposed measures to mitigate or minimize adverse effects; and,
 - make recommendations to the Minister.
- (vii) The Minister reviews the Panel report with the Minister of the initiating agency; should the Ministers disagree, the matter is referred to the Cabinet for decision.
- (viii) The initiating agency incorporates recommendations based on ministerial decisions.
- (ix) Inspection and monitoring will be performed by the initiator and other agencies designated by ministerial decisions.

Most Canadian provinces have enacted overall legislation encompassing assessment. Ontario is the only province which has legislation specifically addressed to the establishment of the Assessment Process, while New Brunswick's provisions are contained in a Cabinet directive.

A separate review agency or mechanism is called for in five of the provinces while in the others this function is assigned to the overall department. Guidelines for the preparation of environmental impact statements have been developed by Alberta, Manitoba, Newfoundland, Ontario and Saskatchewan.

8 CONCLUSIONS

Despite current control measures, the aircraft pollution problem is far from being solved, as evidenced by the increasing numbers of complaints and lawsuits.

In the majority of cases, solving a pollution problem before it occurs is far less expensive than cleaning it up after the facility is in operation. Although many major pollution problems exist which must be solved, unless resources are also allocated to the prevention of future problems, the situation will continue to deteriorate.

To date, many governments have taken some action with regard to aircraft noise and other types of pollution; however, increased government action will be required so that strong policies can be developed with regard to aircraft pollution (such as the acceptability of SST, STOL, VTOL, etc.) and subsequent control measures implemented so that the aircraft pollution problem is reduced. Channels of communication and cooperation must be established among the various levels of government, industry, and the public so that:

- (i) aircraft are designed to be more energy efficient and to have noise and other emissions reduced to more acceptable levels;
- (ii) the adverse effects of aircraft pollution are minimized through proper land use planning and airport site selection;
- (iii) aircraft operations have the reduction of pollution as a major consideration;
- (iv) additional research is conducted so that a better understanding of the effects of pollution is acquired;
- (v) proper planning and implementation of all transportation facilities and operations in wilderness areas are observed to ensure that the special ecological and aesthetic concerns are adequately protected; and,
- (vi) existing aviation pollution problems are cleaned up through adequate allocation of resources.

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